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Editorial

Using Choice Experiments to Assess Environmental Impacts of Dams in Portugal

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Abstract: Despite their well-known benefits in electricity production, dams are also responsible for some adverse environmental impacts affecting particularly the wellbeing of residents of the local communities. These environmental damages have not been included in the cost-benefit analysis of hydropower developments mainly because of the difficulty to determine their value. The prime objective of this paper is to measure the economic values of several environmental impacts due to the dams' activity in Portugal, using a discrete choice experiments approach. With the results of this research paper, we expect to contribute to a more efficient and thorough cost-benefit analysis within the complex process of deciding the optimal location of future dams to be built not only in Portugal, but elsewhere. The addition of this stage to the decision-making process allows the integration of economic, social and environmental dimensions, promoting a richer and more informed decision process.

Keywords: discrete choice experiments; dams; environmental impacts; public attitudes

1. Introduction

The construction of dams, particularly large dams, is often controversial and the surrounding debate has become more heated during recent years. In the origin of this controversy is the association of adverse impacts on the natural and social environments of the local communities, including biodiversity limitation [1,2], impacts on fauna and flora [3–6], flooding of large areas of farmable land [7,8], water quality degradation [7,9], landscape intrusion [10–13], destruction of architectural, historical and archaeological sites [14–17], noise [18], risk of rupture of dams [19–22], and the damages associated with dam removal at end-of-life [23] among others. These impacts have not been traditionally included in the cost-benefit analysis (CBA) of hydropower developments mainly because the process of determining their economic value is far from being straightforward, since there are no markets for the environmental goods and services impacted and, therefore, prices are not available.

However, the inexistence of prices for these environmental impacts does not necessarily mean they have no value, which can in fact be estimated using valuation techniques of non-market goods and services. This paper uses the discrete choice experiments (DCE) approach to measure the economic values of some environmental impacts associated with the operation of dams in Portugal. The work here presented does not focus on one hydropower plant in particular, but on hydropower plants in general. Although this application refers to dams in Portugal, these share characteristics with hydropower plants in other countries and as such the results obtained may be extended with the required adaptations to other settings.

Furthermore, the measurement of impacts in a common unit (normally a monetary value) allows the comparative analysis of the welfare effects for different stakeholders. In this sense it contributes to operationalizing the recommendations of the World Commission on Dams Framework (Directive 2000/60/EC and amendments), regarding the consultation of all parties involved and prescribing unanimity as the criteria for decision making. As the construction and operation of dams is not impact free, a unanimous decision is only feasible if some compensation occurs. The monetary valuation of the impacts is thus a useful tool for devising compensating measures between affected stakeholders.

The remainder of this paper is organized as follows. We proceed with the explanation of the methodology applied, the discrete choice experiments (DCE), with particular emphasis on the design of the questionnaires, a fundamental tool in the DCE approach. This is followed by the presentation and discussion of the results and, finally, some concluding remarks are made.

2. Methodology

The elicitation of people's valuation for environmental impacts of dams has been performed using either the contingent valuation method or the discrete choice method. The contingent valuation method proposes a hypothetical market where participants express their willingness to pay (WTP) for a constructed scenario; on the other hand, choice experiments allow the estimation of individuals' valuation for attributes or characteristics of the scenario. As the focus of this paper is to determine the value that individuals place on specific environmental impacts of hydropower electricity production plants, so as to aid policy decision makers in choosing their size and location -, we opted for the use of discrete choice experiments.

2.1. Discrete choice experiments

The first studies developing the DCE technique date back to the early eighties. The papers by Louviere and Hensher [24,25], and Louviere and Woodworth [26] have become historical reference sources,by opening the discussion of the theory and the logic behind this methodology.

The approach is based on the notion that value is derived from the specific attributes of a good or service, which is in accordance with Lancaster's characteristics theory of value [27]. As stressed by Bateman et al. [28], although it may seem a simple task, describing any good in terms of its attributes is far from being easy to accomplish. Even so, DCE is arguably the simplest of the choice-based approaches in terms of cognitive requirements from respondents who are presented with a series of alternatives and are asked to choose their most preferred option. In the different choice tasks presented, respondents are forced to trade-off changes in attribute levels against the cost of making these changes [29–31].

DCE assumes that respondent *n* will chose among a set *C* of *J* alternatives *(j=1,…J).* Each alternative generates a specific level of utility to consumer *n*, and it is assumed that the consumer chooses the alternative that gives him the highest utility. Let U_{nj} be the utility that respondent *n* derives from alternative j, then alternative j is chosen amongst the alternatives on C if and only if $U_{nj}>U_{ni}$, $\forall j \in C, j \neq i$ .The utility is known to the respondent, but the researcher only knows V_{nj}, the observable component of the utility function [32,33] which depends on observable and measurable components (e.g. attributes, context, individual characteristics). In this sense, U_{nj} might be different from V_{nj} because of unobservable factors designated by ε_{nj}, the random component. Thus

$$U_{nj} = V_{nj} + \varepsilon_{nj}$$

And j is chosen if

$$V_{nj} + \varepsilon_{nj} > V_{ni} + \varepsilon_{ni} \ \ \forall i \epsilon C, i \neq j$$

However, if the utility is random, then the choice is also not deterministic, and we can thus define the probability that respondent *n* chooses alternative *j* as

$$Pnj = \mathrm{prob}\left|\left(V_{nj} + \varepsilon_{nj}\right) > \left(V_{ni} + \varepsilon_{ni}\right)\right| \ \ \forall i \epsilon C, i \neq j$$

$$Pnj = \mathrm{prob}\left|\left(V_{nj} - V_{ni}\right) > \left(\varepsilon_{ni} - \varepsilon_{nj}\right)\right| \ \ \forall i \epsilon C, i \neq j$$

Assuming that the error terms are independent and identically distributed (iid) extreme value type 1, the probability of choice of an alternative from a choice set *C* defines the standard logit specification [34].

Application of DCE involves the development of the following stages: Selection of attributes and specification of attribute levels; Experimental design; Data collection; and Data analysis.

In our study, a detailed list of attributes (environmental impacts) was designed through an extensive literature review on the subject. From consultations among scientific experts, and by using qualitative research methods such as focus groups discussions and "think-aloud" sessions, we selected the most relevant attributes in order to simplify the respondents' choice task. All attributes that were not mentioned in the focus-groups and think aloud sessions were excluded from the study. The selection of attributes took into special account the familiarity and ease of understanding by respondents [35]. As a result, the following attributes were included in the choice sets presented to respondents: significant impact on the landscape; significant impact on fauna and flora; noise production that significantly affects the local population; heritage destruction, and a cost attribute (increase in the monthly electricity bill). Two levels (yes/no) were defined for each attribute except for the cost attribute, which had three (4, 8 and 12 €). The inclusion of the cost attribute allows the estimation of the monetary amount individuals are willing to pay for having a certain scenario of hydroelectricity generation associated with different environmental impacts levels. The chosen payment vehicle was the electricity bill, a form of payment known to all individuals and which does not raise any doubts as to how this could be implemented in practical terms.

Experimental design is the process of combining levels of attributes to generate alternatives sequentially paired. Before settling on a design, some important choices must be performed, namely: number of options in each choice set, which effects are to be estimated (main effects or also combinations), and number of choice sets for each respondent [36]. Through an efficient experimental design (using NGENE software), the attribute levels were combined and paired into choice sets. Each alternative defines a specific form to generate electricity power through hydropower. Each choice set has two alternatives and in total each respondent makes 8 binary choices.

The choice between two unlabeled energy sources *i* by respondent *n* is analyzed through the specification of the Binary Logit (BL) model with cluster correction accounting for the repeated nature of the discrete choices and the potential underestimation of the standard errors by the pooled estimator that ignores correlation across observations [37].

Previous applications of DCE in the valuation of environmental impacts of large dams are scarce, and most applications regard the choice between green versus brown energy sources (for example [38−41]) or between renewable energy sources (for example [42]). Focusing on valuing the environmental impacts of hydropower using DCE three studies deserve a detailed description as they are in some aspects comparable to this study. Sundqvist [43] applied DCE for valuing the environmental impacts of dams in Sweden by Swedish households. The study "provides a good basis for evaluating which environmental improvements are most important for power producers to implement" (paper 4, p.2). The attributes considered in the study were: downstream water level (indirectly covering impacts on fauna and flora); erosion and vegetation (which relates to the effects derived from the size of the reservoir); and impacts on fish life (covering the ability to catch fish in the affected area). The attribute price was included as an increase in the price of electricity per kwh. All attributes had three levels, but for the attribute price, which had 5 levels. Fractional design was implement with each respondent facing 6 choices between a *status quo* option, constant in all choices and resembling the current form of hydropower production in Sweden, and an alternative form of producing electricity using hydropower.

Han et al. [44] applied DCE to elicit the economic value of large dam construction environmental attributes in Korea. The attributes considered, based on literature review and focus groups, were: (i) forest, measured by the number of population living in forest protected area; (ii) fauna, measured by the number of protected fauna species; (iii) flora, measured by the number of protected flora species; and (iv) remains, measured by the level of protection of historical remains; (v) price, measured by increases in water price as water supply was a major concern and dams would also contribute to solving this problem.

Finally, Cretì and Pantoni [45] considered four attributes to characterize the impacts of a dam construction in river Aspe in Southern France: fish conservation (two levels), hydro-morphology (two levels), water quality (three levels) and a rebate in the electricity bill (four levels). They found that all attributes are statistically significant determinants of respondents' utility, with fish conservation being the most valued.

2.2. Questionnaire design issues

Following the recommendations of most literature on non-market valuation [46], we used a face-to-face approach to present the DCE questionnaires. Although interviews are relatively high cost and may be subject to "interviewer bias", this technique presents several advantages, namely it allows the use of visual material and it usually generates high response rates.

The questionnaire was divided in four parts: in an introductory section, questions were presented so as to assess the degree of respondents` familiarity with renewable energy sources (hydropower, wind power, photovoltaic power, and biomass); then there was a valuation section in which individuals were presented with eight different choice sets (Table 1 reports one of the choice sets given to respondents), each consisting of a choice between two alternative ways of producing electricity through hydropower differing on the levels of specific attributes; in a third section, respondents answered questions on their general opinion about renewables; and, finally, a last section included questions on individuals` socio demographic characteristics and environmental preferences. Table 1, reproduces one of the eight choice sets presented to individuals in the hydropower DCE questionnaire. By observing respondents' choices over the eight choice sets, which vary in the level the attributes are present, we are able to estimate the value attributed to each attribute.

Table 1. Choice set example.

Consider the choice between form A of electricity production through hydropower and form B of electricity production also through hydropower. Please tick your preferred option.

	Form A	Form B
Significant impact on landscape	Yes	Yes
Significant impact on fauna/flora	No	Yes
Noise affecting population	No	Yes
Destruction of heritage	Yes	No
Increase in monthly electricity bill €	12	8
Your choice	▢	▢

Each choice set was followed by specific questions to measure the degree of certainty with which individuals would be really willing to pay the amount associated with their choice.

In spite of facing hypothetical scenarios, it is important to know the degree of certainty with which individuals evaluate their WTP in a real situation. Most of the studies on this issue confirm that individuals tend to overstate their actual preferences when asked a hypothetical question [47–51]. Nevertheless, although possibly biased, hypothetical valuations convey useful information about individual`s real WTP. Another possible difficulty with eliciting individuals' WTP for non-market goods is respondents' familiarity with the good or service in question. To control for this effect, questions on familiarity with renewable energy sources and hydropower in particular were included in sections 1 and 3 of the survey.

3. Results and Discussion

Data was collected through personal interviews from a sample of the Portuguese continental population during the first semester of 2014. In total we collected 250 questionnaires. Given that each respondent made 8 choices between two alternatives, we have in total 2000 observations. Regarding the sample characteristics, respondents are on average 49 years old (with a standard deviation of 17 years), 46% of the respondents are male and 36% are employed. Regarding qualifications, 29% of the respondents have a university degree.

Characterizing respondents' environmental concerns, the most important environmental problem associated with the use of energy from fossil fuels is water pollution (66%), followed by CO_2 accumulation (56%) and climate change (43%). The vast majority of respondents are familiar with the production of electricity through wind farms, photovoltaic farms and hydroelectric power stations; geothermal energy is unfamiliar to most respondents. Furthermore, 96% of respondents consider wind energy the most environmentally friendly, followed by photovoltaic (94%) and hydropower (90%). One important indication of the importance attributed to renewable energy is the interest that respondents have in the type of energy source used in the production of the electricity they consume: 34% of respondents consider it very important, while only 6% do not care about the origin of the electricity. The monthly average electricity bill of respondents is approximately 77 Euros (with a standard deviation of 77.55 Euros). Regarding how respondents decide in the choice tasks, 22% indicate they considered all attributes during the choices. Finally, 79% indicate they do not see the installations of energy production on their daily commute. Respondents who see these installations say they most frequently see wind farms and especially from their homes.

For the data analysis, the specification of the binary model included the attributes of the forms of electricity production as explanatory variables. All attributes were statistically significant implying that these are relevant to explain the choices of the respondents. All attributes have a negative sign as expected since the presence of the environmental impact should have a negative effect on respondents' utility level (Table 2).

Table 2. Results for binary logit model with cluster correction.

Variables	Logit Coefficient	Standard error
Constant	2.1155***	0.2044
Landscape	−0.4966***	0.0944
Fauna/Flora	−1.28649***	0.1434
Noise	−0.7753***	0.0628
Heritage	−0.3558***	0.7260
Price	−0.0852***	0.0205
Log likelihood function		−2489.91546
Significance level		0.000

***Significant at 1% significance level.

The “impact of dams on the fauna and the flora” is the attribute considered most important and on average respondents would be willing to pay 15 Euros extra to avoid the presence of this impact. The second most important impact is the “noise produced by dams”, valued on average at 9 Euros per month. The effects on the landscape and the destruction of built heritage are valued at 5.8 and 4 Euros, respectively. In interpreting these results it should be stressed that WTP estimates of welfare loss imposed by the presence of dams are not additive (Table 3).

Table 3. Willingness to pay estimates (Delta method) (euros/month person).

Variables	WTP	Standard error
Landscape	5.8300***	1.1782
Fauna/Flora	15.1030***	3.8913
Noise	9.1016***	2.3059
Heritage	4.1770***	1.5732

*** significant at 1%.

The results obtained are in line with the results obtained in Sundqvist [43], Han et al. [44], and Cretì and Pontoni [45] confirming the relevance of environmental impacts of large dams on consumers’ utility as revealed by the statistical significance of individual attributes. Moreover, despite differences between the attributes selected in the studies, the attributes related to preservation of fauna and flora, which impact respondents’ utility stronger in Sundqvist [43] and Han et al. [44] and Cretì and Pontoni [45] for fish preservation, are also the most significant in this application.

4. Conclusion

The use of hydropower for electricity production has many benefits when compared with other energy sources: it does not generate CO_2 emissions during production, it is renewable, and it is storable to some extent. However it also has important environmental impacts that strongly depend on the location and size of the plant. In this paper we explore the impacts of hydropower energy in the production of electricity on the utility of the general population. Using the attributes of the alternatives as explanatory variables we conclude that the environmental impacts considered in this research have a significant and negative effect on respondents’ utility implying that Portuguese general population is willing to pay higher electricity prices to avoid the impacts considered. Moreover, as the impacts depend on the site and on the size of the dams, policy makers may use this information to integrate these parameters into their decision making process. According to the results obtained, the most important impact, in the opinion of the interviewed population, is the impact on fauna and flora, followed by the impact of noise. Also important, although significantly less, is the impact on the landscape and the loss of built heritage. It should be stressed that for decision making purposes this analysis should be complemented, in each specific case, by an analysis of the welfare effects specifically on the local population, thus contemplating all stakeholders in the decision.

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Conflict of Interest

All authors declare no conflicts of interest in this paper

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